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# Scanning white light interferometry in quality control of single-point tape automated bonding

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**Abstract**

We report on applying a scanning white light interferometry (SWLI) for quality control of aluminum lead single-point tape automated bonding (spTAB). A spTAB process was used to connect Al leads on a thin polyimide flex to Al bond pads on a flexible Al-polyimide cable. In the experiment three different bonding process parameters, i.e. bond force, ultrasonic power, and ultrasonic treatment time were varied in order to maximize the pull force. A custom built scanning white-light interferometer was used to measure the bond height in order to correlate this parameter with the tensile bond force. This force was obtained in a destructive way by a consecutive pull test. All bonds with a height within (7.22 ± 1.80 μm), possessed a tensile strength exceeding 85 mN. This was verified by a separate validation measurement where the pull force of bonds complying with the height requirement was recorded. Based on the 3D observations the conditions for an acceptable bond quality were revisited and refined.


*Keywords:* Bonding; Interferometry

## 1. Introduction

Optical techniques provide non-destructive means for quality assurance in microelectronics production. Typically, 2D imaging of devices during production is carried out [1,2]. For instance the geometry of interconnects, e.g. ball bonds, has been used as a signature of acceptable quality [1].

Scanning white light interferometry (SWLI) is a fast and accurate 3D inspection method [3]. This technique could prove useful in cases where the interconnections are optically accessible after bonding, as with single-point tape automated bonding (spTAB), should the bond geometry provide information about the interconnection quality.

Flexible interconnections and the TAB technique have typically been used in applications requiring dynamical features like inkjet printers and in flat structures such as memory cards and displays [4,5]. Standard materials in flexes for TABing use polyimide as base material and copper as conductor. However, extremely light structures can be realized using thin Al instead of Cu. In addition, being softer than Cu, Al allows a delicate bonding process with low bonding force and ultrasonic power, even at room temperature [6]. Therefore, the Al-technology is an attractive technology for miniaturized components with critical thermo-mechanical features. Moreover, Al–Al bonds are known to be reliable and additional advantage accrues from the fact that the flexible base material can absorb part of the coefficient of thermal expansion (CTE)-based deformations caused by temperature changes in the hard microchip [6]. The bonding process is purely ultrasonic and provides lead-free interconnections.

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The aim of this work is to verify the applicability of SWLI for rapid quality control of spTAB samples. The (bumpless) spTAB was used to assemble samples for optical 3D investigation. Pull tests were used to establish a correlation between the optically measured bond height and the bond strength measured by a pull test.

## 2. White light interferometry

Broadband interference can be used for topographical characterization of mechanical and electrical components [7]. Recently the use of a white light source instead of a narrow band laser for this purpose has increased. The most important property of the white-light interferometer is the fact that the broadband source removes the phase ambiguity associated with laser interferometers. The introduction of new light sources, e.g. blue and white light emitting diodes, the use of fast digital cameras capable of capturing relatively big sample surface areas and the increased calculation power of microcomputers has accelerated the interest to develop automated white light interference profilometers featuring both high resolution and short measurement time.

The instrument used for the measurements reported herein was built at the University of Helsinki [8]. Fig. 1 shows a schematic drawing of the device. Interference fringes on a surface were created by a microscope objective (Nikon 10×or 50×) equipped with a built-in Mirau interferometer. A quartz halogen lamp was used for white light illumination (Philips-projection lamp, type 6958). Because of its short coherence length (ca. 3000 nm), interference fringes occurred only in those areas of the sample where the optical path difference between the interferometer arms was smaller than the coherence length of the light source. A 350 μm-travel-range PI (Physik Instrumente) piezoelectric phase shifter was used to move the objective in 68 nm steps in $z$-direction. At each step the interference image was captured by a CCD camera (Pulnix, type TM 6710, 120 frames/s).

The white light interference fringes are localized in space and therefore provide absolute location. The height information is contained in the fringe visibility (envelope function), from which the height can be extracted. A white-light interferogram can be approximated by an overall constant $I_o(x,y)$ and a series of sinusoidal interference fringes modulated by an envelope function $\gamma(x,y,z)$:

$$I(x,y,z) = I_o(x,y)[1 + \gamma(x,y,z)\cos\phi(x,y,z)]. \quad (1)$$

Since the envelope function varies more slowly than the phase of the interference fringes $\phi(x,y,z)$, the intensity variation can be thought of as an amplitude modulated signal. Thus, a way to measure surface topography is to determine the position of maximum fringe visibility simultaneously for an array of image points, using an interferometer equipped with a mechanical means to alter the optical path difference.

The software for the designed interferometer was developed simultaneously with the mechanical instrument design. The software controls the scan and the capture procedure, i.e. the envelope extracting from the raw image data, the generation of $z$-position information from the envelope signals and the presentation of the data in various formats.

Several algorithms for envelope peak detection exist. They all provide the $z$-coordinate of each sample point. We used the Larkin's algorithm [9] for the fringe envelope peak detection.

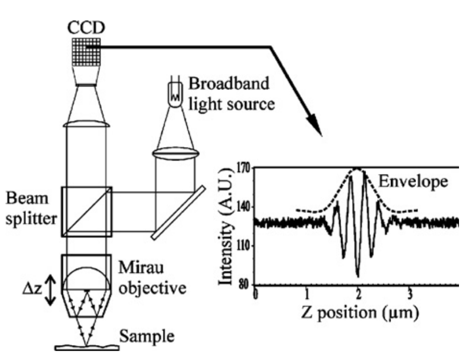


Fig. 1. Experimental setup with the interferometric Mirau-type microscope objective. The piezo-translator changes the distance between the objective and the surface of the sample.

## 3. Single-point tape automated bondings

### 3.1. Components and interconnections

Thin traces of pure Al on a polyimide flex act as conductors in the components studied [10]. The Al traces can be ultrasonically bonded to Al pads on a Si-die (chip-to-flex) or on another polyimide flex (flex-to-flex) through wet-etched openings in the polyimide.

Preliminary work on chip-to-flex type interconnections was previously reported [11]. In this work, flex-to-flex interconnections were studied. In one application [10] such interconnections link control input traces on a flexible hybrid to amplifier chips and silicon sensors. Therefore, a failure in such a bond is lethal for the operation of the entire assembly.

Particularly, a flex cable with 14 μm thick and 82 μm wide pure Al traces on a 12 μm thick polyimide cable was connected to another flex cable. The second cable was made of a 20 μm thick polyimide carrying 30 μm thick and 80 μm wide conducting Al traces. Aluminum, 140 μm by 720 μm, bond pads were located at the end of the traces on the flex.

Images of spTAB Al bonds are shown in Fig. 2. X-shaped spTAB interconnections bonded on flex bonding pads through a bonding window in the polyimide flex are shown in Fig. 2 (left). A magnified image of the bond featuring the tool-induced impression that was analyzed by the SWLI is shown in Fig. 2 (right).